TITLE: Army Aviation FLIR Mission Planning Enhancement

Army Aviation FLIR Mission Planning Enhancement

George G. Koenig, Robert E. Davis and Major Stephen T. Milton
U.S. Army Engineer Research and Development Center
Cold Regions Research and Engineering Center
72 Lyme Road, Hanover, NH 03755

ABSTRACT

Aviators rely heavily on Forward Looking InfraRed (FLIR) imagery to navigate and to rapidly and accurately detect and identify targets. Weather and weather impacted terrain and targets can significantly alter terrain-target infrared contrast relationships impeding an aircrew's ability to effectively use FLIR imagery for mission accomplishment, potentially increasing aviator's exposure to enemy threats and counterattacks, and ultimately decreasing system lethality and survivability. Pre-flight physics-based "through the sensor" infrared synthetic scenes can mitigate the impact of weather by portraying the weather impacted terrain-target infrared battlefield scenes accurately.

The U.S. Army Engineer Research and Development Center (ERDC), the Air Force Research Agency (AFRA), and the U.S. Army Aviation Test Directorate tested the utility of the Infrared Target-scene Simulation Software (IRTSS) system as a mission planning and rehearsal tool for Apache attack aviation. Pre-flight infrared synthetic scene mission enhancement was quantified based on Battle Position (BP) rankings, as compared to the rankings of a Standardization Instructor Pilot (SIP), target detection times, number of target false detects, and number of target non-detects. Questionnaires were used to qualitatively assess the 'value' of pre-flight synthetic infrared scenes as judged by Army aviators.

Predicted FLIR scenes significantly enhance the Intelligence Preparation of the Battlefield (IPB) process, allowing aviation planners to predict FLIR performance, evaluate and select optimal routes, and battlefield positions. Two groups of fifteen Apache pilots participated in the test to determine the impact of infrared synthetic scene simulation on Army aviation mission effectiveness. The control group received the current pre-flight briefing tools, while the test group received current briefing tools plus IRTSS scenes representing the Apache Target Acquisition Detection Site (TADS) imagery consistent with the mission Fragmentary Order. IRTSS scenes improved pilot performance in all test areas. Battle Position selection improved by 75%, target acquisition by 61%, target detection by 41%, and time to detect decreased on the average 6.5%.

INTRODUCTION

Army aviation warfighters rely heavily on Forward Looking InfraRed (FLIR) sensor systems to quickly and accurately acquire and identify targets. FLIR imagery is used for visual cueing for navigation, identifying Battle Position/Firing Position (BP/FP), and orientation in the Engagement Area (EA). FLIR imagery provides a "visual perception" of the battlespace thus enhancing two key enablers of the Objective Force: information dominance and situational awareness. Rules of Engagement (ROE) require Army attack aviators to visually recognize their target before releasing their ordinance. Even under blue-sky conditions, complex spatial and temporal variations in the thermal signatures of natural backgrounds and targets complicate the "visual recognition" of targets using FLIR systems. But, FLIR systems provide a clear and unequivocal advantage for nighttime engagements, and can even provide an advantage over 'looking out the window' during the daytime. Target detection is a contrast radiant intensity issue. In general, the greater the contrast between the background and the target the easier it is to detect the target. In the visible, paint and paint patterns have been developed to basically reduce the contrast between the target and the background. It is more difficult to mask 'hot spots' on vehicle targets thus FLIR systems can offer a clear advantage over optical systems. Weather impacted terrain and terrain-target contrast relationships affect FLIR mission performance (Bryant, 1998). Conditions that degrade FLIR system performance can increase aircraft exposure to enemy threats and counterattacks, increase the time required to detect and identify targets, and increase the time to accurately select BPs/FPs and orienting on EAs, ultimately decreasing system lethality and increasing system vulnerability. Generally, the less contrast between background terrestrial features and between the target and the background, the longer it takes a human to make confirmed recognition (Bryant, 1998). Today, the Army does not have a tactical level capability to predict

FLIR scenes of the battlespace. Warfighters must rely on their ability to mentally translate two-dimensional topographic maps and visual animations to the corresponding FLIR representation of the battlespace. Unfortunately, a one-to-one mapping between visual and corresponding infrared imagery does not exist. Achieving situational awareness in FLIR is a most challenging endeavor (Milton and Williams, 2002). Synthetic infrared scenes generated using physic-based models have the potential, when used as a pre-mission briefing tool, to significantly enhance FLIR situational awareness by allowing aviators to view navigation routes, BP/FP positions, EA appearance, and target-background thermal contrast based on expected environmental conditions at mission time. A Concept Experimentation Program (CEP) was conducted to assess the military utility and value pre-mission, synthetic IR scenes provide to the aviation warfighter.

CONCEPT EXPERIMENTATION PROGRAM

The Concept Experimentation Program provides the Army Training and Doctrine Command Battle Laboratories a method to evaluate and capitalize on emerging technologies, material initiatives, and warfighting concepts while offering the research and development community an effective and efficient method of determining the value added to warfighting capabilities. The Air Maneuver Battle Laboratory and the Aviation Directorate of Combat Developments at Fort Rucker, AL, sponsored a CEP collaborative effort involving researchers at the Engineer Research Development Center (ERDC/Cold Regions Research Engineering Laboratory and ERDC/Topographic Engineering Laboratory) and defense contractors supporting the Air Force Research Laboratory (AFRL) to determine the military use and benefit of predicted IR scenes of the battlespace on Army attack pilot performance. Conceptually, the experiment was done in the context of the tactical operating domain of AH-64A Apache helicopters employing hellfire missiles for high priority targets. The AH-64A uses a Target Acquisition Designation Site thermal sensor, operating in the 8-12 micrometer band, for target detection. This CEP focused on the military worth of predictive TADS scenes and animations and specifically addressed the following issues:

Issue 1. Battle Position Evaluation: Do pre-mission synthetic IR scenes improve the AH-64A pilots' ability to evaluate and rank order BPs?

Issue 2. Target Detection and Identification: Do pre-mission synthetic IR scenes decrease the time it takes to detect and identify targets? Do pre-mission synthetic IR scenes improve target detection (decrease the number of false detects) and improve target acquisition (decrease the number of non-detects)?

Issue 3. Situational Awareness and Risk Mitigation: Does the capability to generate IR scenes from a "look-back" position increase situational awareness thus enhancing risk mitigation?

Issue 4. Enhance Aviation Mission Planning: In the opinion of the test subject would access to pre-mission, synthetic IR scenes (e.g., through Aviation Mission Planning System-AMPS) improve the Intelligence Preparation of the Battlefield process, Battalion-Platoon planning/unit rehearsals and aircrew/aircraft risk mitigation?

The CEP experiment was designed to obtain quantitative and qualitative measurements using IRTSS generated "through the sensor" synthetic images, in a classroom setting, to address and answer the issues stated above.

THE EXPERIMENT

The classroom experiment was conducted July 9-13 2001, at Fort Hood, TX, and was administered by the Aviation Test Directorate (AVTD), U.S. Army Operational Test Command to determine the value added to mission planning and rehearsal of synthetic TADS scenes and animations. The experiment consisted of 30 Apache pilots crossed-leveled by flight experience and placed into two groups: the baseline group and the IRTSS group. Both groups contained company-level officers ranging from WO1 to captain. Both groups received the standard mission planning and rehearsal tools (operations order, topographic map, operational overlay, and Aviation Mission Planning System and bold earth line-of-sight application). The IRTSS group received 'through the sensor' IRTSS predicted TADS scenes and animations. All other aspects of the experiment for the two groups were the same, including the level of training and time to complete the test. The IRTSS group was told the "The IRTSS scenes and animations closely represented what they would see if they actually flew the specific missions as outlined in the operations order". In order to address issues 1 Apache TADS video was collected from 5 BPs associated with two separate EAs. Each EA contained three VISMOD HMMWVs. The same approach was used to address issue 3, but TADS video was collected for four different EAs and a total of 8 BPs. Each EA contained a single VISMOD HMMWV. The Apache TADS IR video was obtained for: 1) the helicopter unmasked to view an area potentially containing target(s), and 2) scans of an (notional) EA containing targets. Pilots were tested individually under the supervision of the AVTD test administrator. A personnel computer was used to view all TADS video and IRTSS synthetic scenes and animations. The pilots from the two groups (baseline and IRTSS) were given the same FRAGmentary Order (FRAGO).

Upon completion of the review of the FRAGO, the pilots had access to their groups' respective mission planning tools. The AVTD test administrators conducted the tests by instructing the pilots to watch a series of pre-recorded and digitized TADS FLIR video. The test did not evaluate the IRTSS GUI or the validity of the IRTSS generated TADS synthetic scenes or animations.

SYNTHETIC SCENE GENERATION MODEL: IRTSS

Physics-based modeling systems used to generate synthetic IR scenes must have the capability to predict the radiance at the aperture of an IR sensor, including the impact of atmospheric transmission, over the spectral response band of the sensor. This entails thermal models that predict the energy and mass transfer processes, atmosphere-surface interactions, and suitable computer architecture. Figure 1 provides a notional flow of information from the geophysical data bases required for model initialization to rendered synthetic scenes. We used a modified version of the Infrared Target-scene Simulation Software (IRTSS) developed by Radex Corporation under Air Force Research Laboratory (AFRL), Hanscom AFB, MA (Seeley and Luker, 1998) sponsorship. Because of limitations imposed by the sensitive nature of performance specifications of military sensor systems, the TADS sensor system was modeled using a top hat response function over the spectral interval from 8 to 12 micrometers.

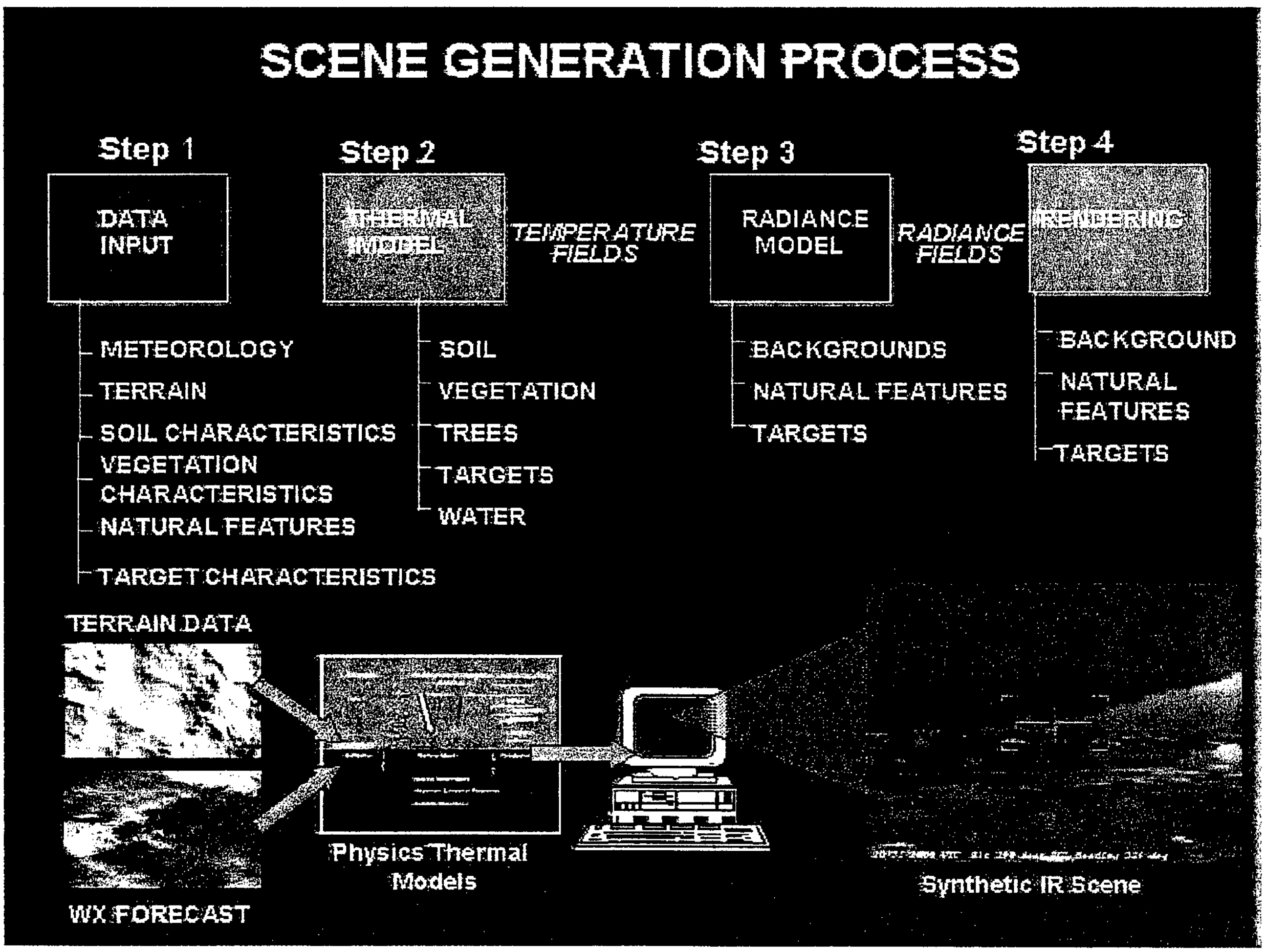

Figure 1. Notational chart of the process to predict IR scenes. Four distinct modules involved in the process: model input data, predicting the temperature fields, generating the radiance fields, and rendering the synthetic IR scene.

Geophysical data requirements for synthetic scene generation

The process of generating synthetic IR scenes starts with the specification of the geophysical data associated with the location to be simulated. The geophysical information required consists of: digital terrain data, terrain feature data, and the physical, thermal and optical properties associated with the feature data. The digital terrain data for the Fort Hood experiment was obtained from various Geographic Information Systems, including those at CRREL, TEC, the Fort Hood Integration Training Management (ITAM) office, and Pacific Meridian Corporation for an area of 20 by 20 km with a spatial resolution ranging from 1 to 3 meters. The terrain elevation data is used to calculate the slope and aspect of the terrain, at each elevation posting, required to correctly ascertain solar loading. The feature information provides the surface soil type, sub-soil type, surface vegetation, and the thermal, optical and physical properties associated with the terrain feature data. The vegetation can be: no vegetation-bare soil, grass, or canopy. Canopy, information consists of: canopy type (deciduous or coniferous), canopy density. and basic canopy physical information (tree height and crown diameter). The canopy information had insufficient spatial resolution to support the CEP synthetic scene generation requirements. In general, the Apache pilots indicated it was not necessary to model every tree and branch, but it was necessary to have the location of tree clusters notionally correct. The canopy feature data missed many of the individual tree clusters and in areas of more continuous canopy cover missed gaps in the canopy that were large enough and interconnected to the point where it was possible to move military vehicles through the canopy. To rectify this problem, CRREL developed semi-automated, interactive techniques to add and remove trees from the original canopy cover information using satellite imagery.

CRREL installed an automated weather station near the Jack Mountain training and maneuver area. The weather station was operated continuously from 1 October 2000 until 30 April 2001. The weather data collected consisted of total and diffuse downwelling solar radiation, upwelling solar radiation used to compute albedo, upwelling and downwelling infrared radiation, air temperature, relative humidity, wind speed and direction, precipitation amount and rate, and IR thermometer measurements of surface temperature. The meteorological information is used to initialize IRTSS and as boundary conditions for generating the synthetic TADS scenes. A minimum of five days of weather information is required to "spin up" IRTSS to achieve thermal stability before synthetic scenes can be generated.

Thermal and Thermal Radiation Models

The thermal models employed in IRTSS were developed under the Joint Test and Evaluation Smart Weapons Operability Enhancement (JT&E SWOE) program (Welsh, 1994: Koenig et. Al. 1995; Welsh and Link, 1995). The SWOE models, and IR synthetic scenes produced using the SWOE models have undergone significant validation (Welsh, 1994; Siegel and Castellan, 1988). The results of the validation of the SWOE models indicate absolute accuracies on the order of a few degrees Kelvin and relative accuracies on the order of one-degree Kelvin. IRTSS uses SWOE models for bare and snow covered ground, forest areas, and vegetation over ground. The physics-based thermal models predict the surface temperature for a series of relatively homogeneous polygons with uniform thermal properties and surface features (Kress, 1992; Ballard, 1994). Homogeneity is based on the slope and aspect of the terrain, soil type, and surface vegetation, i.e. grass vs. forested areas. The soil/snow thermal model is based on the work of Jordan (1991), which simulates most of the important physical processes in snow, but assumes that conduction dominates heat transfer in the soil. The vegetation model follows the approach of Balick et al (1981) and is coupled with the soil/snow model. Solar and infrared radiation interactions between the soil surface and the overlying vegetation are modeled, but physical processes like root zone moisture uptake are not. The canopy model follows the scheme originated by Verhoef and Bunnik (1975) and extended by Smith (1981). Smith used expressions for the canopy energy and mass balance assuming a plane parallel five-layer canopy model (three canopy layers, an atmospheric layer above the canopy, and an underlying soil layer) with uniform canopy properties. Again, the solar and infrared radiation interactions between the soil and the canopy are modeled. The original SWOE model suite included a series of models to compute the spectral thermal radiation associated with natural terrain features in the spectral region from approximately 1 to 20 micrometers. These models included emitted thermal radiation and primary and secondary reflection of skyshine and thermal emitted radiation from scene elements. Because of the computation expense, IRTSS adopted a much simpler approach. Only the emitted thermal radiation is modeled using Stefan-Boltzmann's law. Target temperatures and the associated emitted thermal radiation are calculated using Multi-Service Electro-optic Signature (MuSES) (Rynes, et. al., 2000). The atmospheric transmission of the emitted thermal radiation from natural backgrounds and targets is handled using the DoD model standard for atmospheric transmission, MODTRAN (Berk, et. al., 1989).

Infrared Target Scene Simulation Software

IRTSS provides the capability to generate "through the sensor" predicted IR, night vision, and visible scenes and animations of weather impacted natural backgrounds and targets. Originally developed to support Air Force (high and fast) weapons

systems, IRTSS was modified to support Army Aviation (low and slow) Forward Looking Infrared TADS systems on Apache AH-64 helicopters. The Army version of IRTSS has added trees and structural features (buildings, etc.) to portray realistic line-of-sight obscurations that could potentially be encountered during an Army aviation mission. IRTSS provides the Army aviation warfighter with pre-flight awareness of the impact of weather and terrain as seen through the TADS system.

IRTSS runs under a client-server architecture on either a UNIX or LINUX based computer system. Scenario generation is achieved using a Graphical User Interface (GUI) that provides capabilities that increase situational awareness. For example, mask-unmask scenario generation, a look-back capability, terrain following fly through, and a 360-degree EA fly around to ascertain the best avenue of approach to an EA and best BP to unmask for target kill. For the CEP, IRTSS incorporated a sensor model representing a NATO FLIR system, with sensor fields of view and sensor characteristics similar to the Apache TADS. Therefore, the IRTSS generated scenes and animations represented a credible surrogate for the CEP test subjects, displaying what the Co-Pilot/Gunner would see on an actual TADS system flying the FRAGO. Figure 2 shows a comparison of an IRTSS generated scene to the corresponding TADS scene digitized from the actual video footage. Viewing geometry, location within the Fort Hood test range, time of day, and weather conditions are the same for the generated scene as the TADS video. The sequence of events to generate a synthetic scene is fairly straightforward. First, the user specifies a geographic location populated with targets from the databases packaged with the IRTSS system. Next, the user executes IRTSS using automated weather data, or locally collected weather information, as was the case with the CEP experiment. Using automated weather data from a mesoscale weather model (for example, MM5 or the IMETS/BFM) would provide a prognostic capability allowing the generation of synthetic scenes over the forecast period of the mesoscale weather model. Model execution takes several minutes. Once the thermal fields associated with the scenario have been generated, synthetic scene(s) can be generated using different ranges, altitudes, and headings without rerunning the thermal models. IRTSS presently comes bundled with several geographical data sets; over 50 different target geometries including buildings, bunkers, surface-to-air missile (SAM) sites, and wheeled and tracked vehicles; and several sensor models.

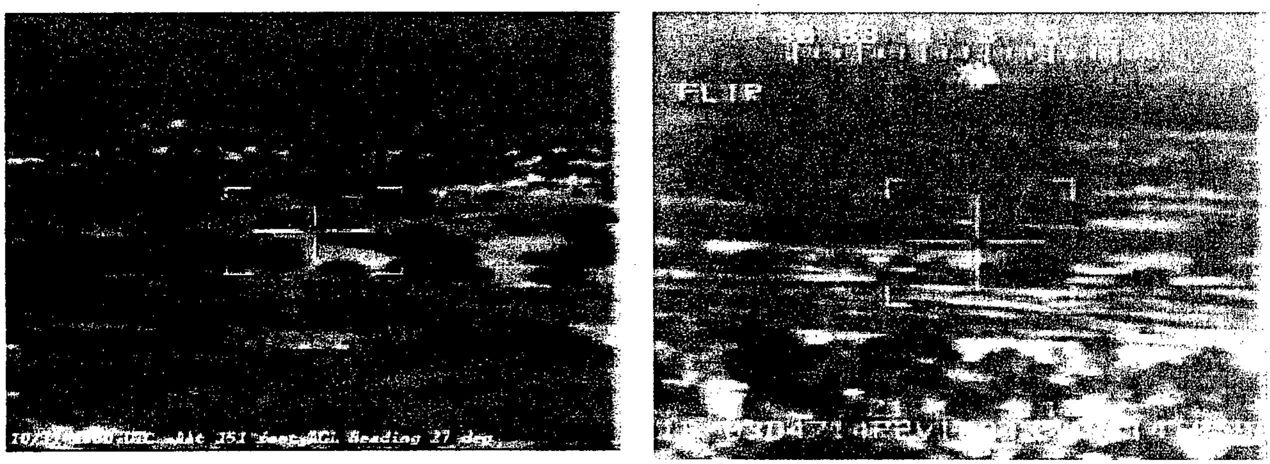

Figure 2. Comparison of an IRTSS scene (left panel) and actual AH-64 TADS FLIR scene (right panel) for the same location, time, and weather conditions. Both have medium field of view, white-hot polarity.

RESULTS

The Army Test and Evaluation Command (ATEC) conducted the formal analysis of the CEP data using a series of statistical and categorical procedures to directly address issues 1- 4. Key elements of the analysis conducted by ATEC have been extracted from the ATEC report titled "Test Report for Forward Looking Infrared (FLIR) Mission Planning Performance Enhancement", report 2001-AVN-1105, October 2001 and presented below.

Issue 1. Battle Position Evaluation: In order to establish a standard of reference, an aviation Standardization Instructor Pilot with access to all materials, including live pre-recorded TADS videos and IRTSS products, established the rank order of the five BPs for each EA. This ranking was considered 'truth'. As indicated earlier, the baseline group received the standard planning tools while the IRTSS group received both the standard planning tools, IRTSS scenes looking from the BP toward the EA, "look backs" from the EA to the BP, and animations of unmasking and scanning within the EA. The "look back"

provides the pilot with some idea of how he is silhouetted against the background. In general, the greater the clutter in the background the more difficult it will be to detect the aircraft. The standard planning tools consisted of: FRAGO, 1:50,000 topographic maps with the position of the BPs and corresponding EAs, Line-Of-Sight (LOS) plots from the BPs to the EAs on a 1:50,000 scale map from the Aviation Mission Planning System (AMPS) in increments of 50 feet from 50 feet to 200 feet elevation, and a copy of tasks, conditions, standards and other reference material. The test subjects had 20 minutes to review the material associated with each EA and were then asked to rank the BPs. ATEC used the Spearman Correlation Coefficient to determine the correlation between the BP rankings for the baseline group and the IRTSS group, and the SIP ranking of the BPs. At the 80% confidence level for EA Maim the BP rankings of 8 of the 15 pilots in the IRTSS group correlated with the SIP rankings while 4 of the 15 pilots in the baseline group correlated with the SIP rankings (see highlighted rows in table 1). This equates to a 100% improvement in BP rank order relative to the SIP (truth) BP rank order. At the 80% confidence level for EA Injure the BP rankings of 6 of the 15 pilots in the IRTSS group correlated with the SIP rankings while 4 of the 15 pilots in the baseline group correlated with the SIP rankings. This equates to a 50%improvement in BP rank order relative to the SIP (truth) BP rank order. Table 1 is the ATEC analysis. Post-test surveys showed 100% of the pilots in the IRTSS group indicated IRTSS scenes and animations helped in the selection of the optimal BP. Every IRTSS pilot indicated the IRTSS unmasking animation clearly showed the impact of vegetation (trees) on LOS and was an improvement over the AMPS bold earth LOS. For example, CPT G. Heap, Company Commander, 1-4 Avn. BN, 4th ID, stated "Accurate vegetation data provided more FLIR visual cues ..... makes pre-mission EA development easier...".

Table 1 Frequency Distribution of Spearman Correlation Coefficients by Battle Position

	BP MAIM		EA INJURE	
Coefficient Range	Baseline	IRTSS	Baseline	IRTSS
<0	3	1	1	1
0 – 0.2	4	3	1	2
0.21 – 0.4	1	0	3	4
0.41 – 0.6	3	3	6	2
0.61 – 0.8	2	5	3	1
0.81 – 1.0	2	3	1	5

Issue 2. Target Detection and Identification: After allowing 5 minutes for "mission planning", each test subject viewed sequentially 8 target detection scenarios. Each scenario consists of an average of 60 seconds of TADS video from a BP scanning an EA containing a single VISMOD HMMWV. For this test 4 EAs (EA shell-3 BPs, EA Bravo-3 BPs, EA Graham-1 BP, and EA Stampede-1 EA) and 8 BP were used. All test subjects previewed the same planning information and viewed the target scenarios in the same order. In addition to the IRTSS scenes, the IRTSS group viewed animations scanning the EA from the BP(s) associated with that EA. To minimize potential biasing of the IRTSS test subjects, the direction of scanning in the animations did not correspond to the direction of scanning on the TADS video. The metrics used to quantitatively address issue 2 consists of the time to detect, the number of false detections, and the number of failure to detect (non-detects). Test subjects were asked to indicate to the test administrator when they believed they detected the target in the TADS video. At this point the test administrator noted the time since the start of the video and asked the test subject to point to the location of the target on the video display. If the test subject correctly identified the target location the time to detect was recorded. If not, a false detect was noted and the video and timer started from the stop point. This procedure was repeated until the test subject correctly identified the target location or the video ended. If during the course of the test, the test subject did identify the correct target location, the number of false detects and the total accumulative time to detect was noted. If the subject did not identify the target location during the course of the test a non-detect or failure to detect was recorded. The procedure was followed for all eight scenarios. For each false detect the test subject was given a 5 second penalty. While this value is somewhat arbitrary, the normal mode of operation for AH-64 Attach pilots is to operate their TADS system in Medium Field Of View (MFOV) and to switch to Narrow Field Of View (NFOV) to confirm target detection. If target detection is not confirmed, they switch back to MFOV and continue to search for the target. This process can take on the order of 5 seconds and hence the 5-second penalty imposed for a false detection. The results of the ATEC analysis are presented in table 2. The number of target detection scenarios is 120 (15 pilots per group, times 8 BP). The BPs associated with the EAs have been numbered. Some of the BPs are used to view two different EAs. In this case, the BP number is the same for the different EAs. ATEV used the Student t-test at the 90% level of significance to test for differences between the baseline group and the IRTSS group. For the time to detect, only the analysis of EA Bravo indicated a significant difference between the two groups. While a penalty was assessed for false detects, no additional time penalty was added for non-detects. In the opinion of the pilots, the scenarios associated with EA Bravo were the most challenging.

Table 2. Battle Position and Engagement Area Mean Detection Times (Seconds)				
Engagement Area	Battle Position	IRTSS Mean Time	Baseline Mean Time	Statistically Significant Difference
Bravo	5	41.2	60.3	Yes
	6	33.5	38.2	No
	7	14.1	16.5	No
	All	29.6	38.3	Yes
Graham	3	20.5	19.3	No
	All	20.5	19.3	No
Shell	4	34.9	27.9	No
	5	18.7	18.5	No
	6	36.1	36.3	No
	All	29.9	27.6	No
Stampede	5	35.4	33.6	No
	All	35.4	33.6	No
Overall		29.3	31.3	No

The student t-test at the 90% significance level was also used to determine if there was a significant difference between the two groups on the number of false detection. The result of the ATEV analysis indicates there is a significant difference at the 90% significance level. Table 3 is a breakout of the false detects for the two groups by EA and BP.

Table 3. Number of False Detections by Battle Position and Engagement area			
Engagement Area	Battle Position	IRTSS	Baseline
Bravo	5	5	16
	6	1	7
	7	3	0
	All	9	23
Graham	3	0	0
	All	0	0
Shell	4	2	6
	5	0	0
	6	4	2
	All	6	8
Stampede	5	5	3
	All	5	3
Overall		30	34

ATEV also used the student t-test and a 90% significance level to test for a significant difference between the two groups for the number of non-detects or failures to detect (Table 4). Again, the analysis indicated there was a significant difference in the number of failures to detect between the two groups. More importantly, but not quantified, is the fact that failure to detect implies mission failure.

Finally, to insure that there were no differences within a group for the scenarios associated with the different EAs for each test (time to detect, number of false detections, and the number of failures to detects) the within group data was tested for homogeneity. The homogeneity tests confirmed that the data amongst EAs for each group for each test was not significantly different.

Issue 3. Situational Awareness and Risk Mitigation: Issues 3 and 4 were addressed qualitatively using a series of questions. Before the test subjects answered the questionnaires, the baseline group was exposed to the IRTSS capabilities and products. This was deemed necessary since some of the questions were of the form "In your opinion do you think an IRTSS pre-mission visualization capability would improve ....". Some of the questions posed to the test groups were:

- " Would this capability (IRTSS) improve pilot navigation, route selection and ingress/egress planning?"

- " Would you find a pre-mission FLIR look-back capability provides increased situational awareness useful for risk mitigation?"
- " Would pre-mission FLIR scenes assist to orient faster on an EA?"
- " Would a pre-mission FLIR planning tool help with crew coordination in BP operations?"

ATEC, based on the answers from both groups to the questions posed, concluded a "look-back capability in the opinion of the pilots increases situational awareness useful for risk mitigation" and "all pilots overwhelmingly feel that IRTSS would assist in situational awareness and risk mitigation".

Table 4. Number and Percentage of Failures to Detect the Target by Battle Position and Engagement Area

Engagement Area	Battle Position	IRTSS Number of Failure to Detects	IRTSS Percentage of Failure to Detects	Baseline Number of Failure to Detects	Baseline Percentage of Failure to Detects
Bravo	5	2	13	6	40
	6	2	13	5	33
	7	0	0	1	6.7
	All	4	8.9	12	26.7
Graham	3	0	0	0	0
	All	0	0	0	0
Shell	4	0	0	0	0
	5	0	0	0	0
	6	1	6.7	0	0
	All	1	2.2	0	0
Stampede	5	0	0	1	6.7
	All	0	0	1	6.7
Overall		5	4.2	13	10.8

Issue 4. Enhance Aviation Mission Planning: According to the findings of the ATEC analysis all pilots indicated that the delivery of pre-mission, synthetic FLIR scenes through AMPS would improve the IPB process planning and unit rehearsals.

CONCLUSION

IRTSS predicted synthetic FLIR scenes provide the warfighter with an operational capability not available today. It allows mission planners to directly and quantitatively account for weather when determining an optimum mission profile for both the tactical situation and the impact of environmental conditions on potential mission success. Enhanced aircrew situational awareness during mission execution is a second benefit associated with a pre-flight IRTSS capability. Pre-mission views of the EA IR clutter and the relative contrast between the target(s) and the immediate background facilitates long-range target detection and positive target identification (Bryant, 1998). IRTSS translates information dominance into readily assimilated situational awareness by fusing tactical intelligence with weather and depicting weather effects in a form that a non-meteorologist can easily understand and apply. The CEP has demonstrated that there is utility in providing Army Attack Aviators with pre-mission and pre-flight synthetic IR scenes generated from a physics-based model like IRTSS. If predicted FLIR capabilities are to enter the formal materiel acquisition process, the IRTSS technology is mature enough now to enter the life cycle at the system development and demonstration phase, thereby significantly reducing the time required for fielding (Milton and Williams, 2002).

REFERENCES

Balick. L. R., R. K. Scoggins, and L. E. Link 1981, Inclusion of a Simple Vegetation Layer in Terrain Temperature Models for Thermal IR Signature Prediction, *IEEE Transactions on Geoscience and remote Sensing*, GE-19(3):143-152.

Ballard, J. R. 1994 Grayling I Information Base Procedures for Generation of Synthetic Thermal Scenes: Final Report, SWOE Report 94-1, US Army Cold Regions Research Engineering Laboratory, Hanover, NH.

Berk, A., L.S. Bernstein. and D.C. Robertson, "MODTRAN: A Moderate Resolution Model for LOWTRAN 7', U.S. Air Force Phillips Laboratory, Geophysics Directorate, Hanscom AFB, MA 01731, Rept. No. GL-TR-89-0122, 30 April 1989.

Bryant, E. V., 1998, A Process Simulation Design to Assess Promising Technologies Relevant to F/A-18 Aircrew Target Recognition, Thesis: Masters of Science in Information Technology Management, September 1998, Advisor: William K. Krebs, Department of Operational Research, Associate Advisor: Terrance C. Brady. Department of Systems Management, Naval Postgraduate School, Monterey, CA 93943-5000.

Jordan, R. 1991 A one-dimensional temperature model for a snow cover: Technical Documentation for SNTHERM.89, USA Cold Regions Research and Engineering Laboratory, Special Report 91-16.

Koenig, G.G., Welsh, J.P., Wilson, J., Smart weapons operability enhancement synthetic scene generation process, SPIE—The International Society for Optical Engineering. Proceedings, 1995, Vol.2469, Targets and backgrounds: characterization and representation, Orlando, FL, Apr. 17-19, 1995. Edited by W.R. Watkins and D. Clement, p.254-265

Kress, R. M. 1992 Information Base Procedures for Generation of Synthetic Thermal Scenes: Final Report, SWOE Report 92-1, US Army Cold Regions Research Engineering Laboratory, Hanover, NH.

Milton, S. and R. Williams, 2002, "Mission Plannign and Rehearsal Tools for the Legacy, Interm, and Objective Forces," *Army AL&T*, May-June 2002, p 42-44.

Rynes, P., A. Curran, K. Johnson, D. Levanen, E. Martila, and T. Gonda, 2000, "Ground Vehicle Target Modeling with the Multi-Service Electro Optic Signature Code (MuSES)", *Eleventh Annual Ground Target Modeling & Validation Conference"*, Houghton, MI, 15-17 August 2000.

Seeley, G. and S. Luker, 1998, Infrared Target Scene Simulation Software, *Battlefield Atmospherics and Cloud Impacts on Military Operations [BACIMO] Conference*, AFRL Hanscom AFB, MA 12/1-12/3 1998, p. 340.

Siegel. S. and Castellan, N. J. Jr. 1988 *Nonparametric Statistics for the Behavioral Science (second edition)* New York: McGraw-Hill.

Smith, J.A., K.J. Ranson, D. Nguyen, L.K. Balick, L.E. Link, L. Fritchen, and B.A. Hutchison 1981 Thermal vegetation canopy model studies, *Remote Sensing of Environment*, 11:311-326.

Verhoef, W., and N.J.J. Bunnik 1975 A Model Study on the Relations Between Crop Characteristics and Canopy Spectral Reflectance, NIWARS publications No 33, 3 Kanaalweg Delft, The Netherlands, 89p.

Welsh, J.P., 1994, Smart Weapons Operability Enhancement (SWOE) Joint Test and Evaluation (JT&E) Program. Final Report, U.S. Army Cold Regions Research and Engineering Laboratory. SWOE report, Aug. 1994, No.94-10, Var. p., ADB-194 042.

Welsh, J.P., and L.E. Link Jr., 1995, Synthetic Scene Generation Process for Smart Weapons, Army RD&A, July-Aug, 1995, p33-36